THE PRE-CAMBIAN SYSTEM IN WESTERN AUSTRALIA.

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By

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CONTENTS.

I.—Introduction.

Pre-Cambrian rocks carry most of the mineral wealth of Western Australia, and therefore have been more studied than any group of rocks in the State. Geologists have described the characters of the various series contained in the Pre-Cambrians of a number of mining centres. But these places are separated by far larger tracts, the geology of which is only known in a broad way, and this isolation combined with the entire absence of fossils makes a wider correlation difficult. It seems to me, however, that some attempt at a general description of the group, more detailed than those given by Woodward (1895)* and Maitland (1919) is justified, especially as it will draw attention to many unsolved problems and diversities of opinion and will remind the geologists of our Society how much work both in field and laboratory lies close at hand.

* Dates in parentheses refer to papers listed in Section VIII.

II.—Distribution and Character of the System.

Of the 975,920 square miles occupied by Western Australia the latest geological map (Maitland, 1919) shows about 600,000 square miles* geologically mapped. Of this area about 380,000 square miles are occupied by Pre-Cambrian rocks.

Speaking broadly, we may say that, except in the Kimberley, Palæozoic and later rocks occupy a comparatively narrow coastal strip which passes into a broad belt running eastwards from the coast between Condon and Derby. Also a great band of comparatively youthful rocks runs northward from the Great Australian Bight, but whether this completely separates the Pre-Cambrians of the Goldfields from those of the borderland of Western and Central Australia is not known.

Comprised in the Western Australian Pre-Cambrian System is a very great variety of rocks, which lithologically may be grouped into—

1. Metamorphosed and unaltered acid igneous rocks.
2. Metamorphosed and unaltered basic and ultrabasic igneous rocks.
3. Metamorphosed and unaltered sediments.

North of Lat. 26°, the clearly sedimentary facies of the group predominates and a very prominent series of trend-lines runs east and west; south of Lat 26° the igneous facies is the more prominent and the trend is N.N.W. and S.S.E. as is shown, not only by the strike of the planes of schistosity, but also by the trend of the long axes of the patches, mainly of basic igneous rocks, which are scattered over a larger area of more acid rock, like chains of islands in a sea. In spite of these broad distinctions, however, sediments do occur in the southern area, igneous members of the system do cover considerable areas in the northern part of the State, and an east-west trend, crossing the much more obvious N.N.W. trend-lines occurs in many places south of Lat. 26°—as, for example, in the Stirling Range,† at Yuin (Jutson, 1914 *c*), and at Sandstone (Gibson, 1908), where the jasper bars run east and west.

It will be convenient, for descriptive purposes, to divide the Pre-Cambrian area of Western Australia into five provinces: the East, extending from the South Australian Border to about long. 127° E.; the West, extending eastwards from the coast to about long. 116° 30 E., northwards to about lat. 27° S., and also following round the south coast so as to include the Phillips River Goldfield; the Central lying between the East and West Provinces and extending north to about lat. 26° S.; the North-West covering the greater part

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* I am indebted to Miss E. Lamborne, B.Sc., for the more exact estimations to which these round numbers approximate.

†Positions of places, districts, etc., mentioned in the text will be found in Section IX.

of the Peak Hill, Gascoyne, Ashburton, Pilbara and West Pilbara Goldfields; and the Kimberley at the north end of the State. After some discussion of details, it will, I think, appear that each "Province" shows a certain amount of individuality in the character of its Pre-Cambrian rocks.

To establish any satisfactory general sequence in such a medley of rocks is obviously a difficult task, and, in order to arrive at any conclusions without entering on a very long discussion, it will be necessary to be apparently dogmatic and to omit mention of such earlier views as have been adopted or rejected by the majority of later workers.

III.—Age of the Whole System.

Maitland (1919, p. 8) writes regarding the supposed Pre-Cambrian age of this great group that there is only one instance on record in which age-determination rests on palæontological evidence. "In the Kimberley Division certain limestones, sandstones, quartzites, etc., have yielded lower Cambrian fossils . . . ; these fossiliferous beds are considered, and may be, newer than the schistose rocks of the vicinity . . . . . No actual junction has been noticed between the schists and the fossiliferous strata."

We are thus faced at the outset with lack of sufficient proof that the rocks under discussion *are* Pre-Cambrian. Assuming that the Kimberley metamorphic rocks are Pre-Cambrian—which is probable—there lies between them and the much larger areas of metamorphic rocks to the south a gap of two or three hundred miles covered (Maitland, 1919—map) by Carboniferous rocks, and, since the oldest fossiliferous rocks found in this southern area are Permo-Carboniferous, there is no absolute proof that the southern facies of the Western Australian metamorphic rocks is older than early palæozoic.

Nothing, however, is to be gained by labouring this point further, and for the rest of this address I shall speak without reservation of the whole series as Pre-Cambrian.

IV.—Relation between Granite and Greenstone.

In every part of the State, whatever other members of the Pre-Cambrian group may be absent, "greenstone" (*i.e.*, metamorphosed basic igneous rocks generally epidioritic in character), and granite are almost invariably present. The mutual relations of these two key rocks are therefore so important for the unravelling of the relative ages of the other types with which one or both will somewhere be seen in contact, that a discussion of their relative ages may well precede any attempt at establishing the general order of succession in the Pre-Cambrians.

Most parts of the West Province are composed of granite or gneiss cut by doleritic and gabbroid dykes which have been dynamically metmorphosed to epidiorite or even to hornblende schist, whereas the granitic rocks of the East Province are cut by great dykes of unaltered gabbro and dolerite and are themselves intrusive into epidiorites. Again, the granites of the Central Province are intrusive into epidiorites and are only to a minor degree cut by later dolerites and gabbros. In the North-West Province the granites are cut by epidiorite dykes and are themselves intrusive into older greenstones.

There is thus a marked contrast between the coterminous West and Central Provinces, and we are faced with the alternatives that the granite of the West is older than that of the Central Province, or that the epidiorite of the West is younger than that of the Central Province.

Now, at Bolgart occurs an epidiorite belt which (Feldtmann, 1920, p. 27) closely resembles the Central Province greenstones and probably forms the westernmost belt of these rocks. Feldtmann finds that the epidiorite is cut not only by acid rocks, but also by another system of epidiorite dykes, which also cut the acid rocks and are undoubtedly part of the series which cuts the Darling Range granite. Also, Montgomery (1908) believes that the greenstone dykes of Wagin and Darling Range are not quite the same in character and occurrence as the greenstones of the Central Province.

Again, near Ravensthorpe, where epidiorites of two ages occur, Maclaren (Montgomery & Maclaren, 1914) regards one series of these rocks as almost certainly older than the granite, while Woodward (1919) makes both younger than the granite.

Moreover in the Central Province in the south part of the Yalgoo Goldfield, Talbot (1920 *b*) noted a series of epidiorites which cut both ordinary greenstone and granite; and in the Yilgarn Goldfield (Blatchford and Honman, 1917, p. 68) the main body of the greenstone is intruded by hornblendite which is probably younger than the main granite, while the dolerites which at Forrestania (p. 131) appear to cut the granite are said to be similar to the Canning River dolerites (near Perth). Another similar instance is given in Blatchford and Honman, 1917, p. 161.

Particulars of the question of the relative ages of granite and greenstone in the North-West Province are scanty, but Maitland (1909, pp. 43 and 95) mentions an occurrence of "greenstone" dykes in granite at Mt. Samuel and Eramurra Creek. "Greenstone" implies rather epidiorite, like that which cuts the granite of the West Province, than unaltered gabbro or dolerite like that which cuts the granite of the East Province; but it is possible that "greenstone" is used by Maitland in a more general sense here, and that the greenstone dykes which he describes are the much younger gabbros and

dolerites of which there is a great development in this region—as, for example, near Corunna Downs homestead (Maitland, 1908, Frontispiece).

Available evidence therefore favours the view that the granite of the North-West, West and Central Provinces is substantially of the same age, but that in the West (and North-West?) Provinces occurs a later epidiorite than that forming the greenstone belts of the Central Province, although a few occurrences of the later epidiorites have been found near the western boundary of the Central Province. The question is, however, by no means as simple as may perhaps appear from the above statement, for it will be found on consulting the sections on the Yilgarn Series and on the later acid igneous rocks, that the granite is not all of one age.

V.—Relative Age, Character and Distribution of the Various Series of the Western Australian Pre-Cambrian System.

In this section will be outlined briefly the lithological character, etc., of the various series of which the Pre-Cambrian Group of Western Australia is composed. These series will be arranged in what seems to be the most probable order of succession, the oldest being placed first.

A.—Yilgarn Series.

In the Central Province the greatest development of these rocks is found in the Yilgarn Goldfield—hence the name which I suggest may be applied for convenience of reference, to the series throughout the State. At Westonia, Bullfinch, Parker Range, Marvel Loch and Ennuin (Woodward, 1912*a*, Blatchford, 1915, Blatchford and Honman, 1917) are found "chiastolite and andalusite shales, quartzites, graphitic quartzites and crushed quartz conglomerates" which Blatchford and Honman consider to be the oldest series of rocks in the Yilgarn Goldfield. Woodward (1912*a*) also suggests that the hornblende-biotite and albite-muscovite granite of the north part of the Yilgarn Goldfield may be of sedimentary origin. Mention of this and other areas of granite-like rocks which are thought by some to be highly metamorphosed sediments will be found in subsection D.

Probably the conglomerate series at Kanowna (Blatchford and Jutson, 1912) is to be classed with the Yilgarn Series. These conglomerates have been dynamically metamorphosed and also interstitially intruded by a rock now metamorphosed to amphibolite.

Under this series also may possibly be included the schists of Gibraltar centre near Coolgardie, since Blatchford (1913), supported by petrological work, regards them as sedimentary, and since there does not seem to be any clear evidence of their age

relative to the Kalgoorlie ("greenstone") Series. Feldtmann, however (1922), considers that they are either sheared greenstones (Kalgoorlie Series) or a sheared grano-diorite different in age from the Kalgoorlie Series.

Between Warriedar and Yalgoo (Specimens obtained by Mr. Maitland and myself, descriptions not published) and near Mt. Kenneth (Talbot, 1920*b*, p. 9) are occurrences of highly metamorphosed rocks which in the field and under the microscope give evidence of their sedimentary origin. Other metamorphosed rocks at Yandhanoo Hill and at Warriedar mentioned later under the Mosquito Creek Series may also belong to the older Yilgarn Series.

Gibson (1909, p. 18) in the country near the transcontinental railway route found that in the large area occupied by granite of the ordinary type, is a belt of garnetiferous gneiss running from Simon Hill for about 100 miles in a N.N.E. direction. This he regarded as older than the granite, and it may therefore belong to the Yilgarn Series.

Several other reported occurrences of "older granite," mentioned under the heading of Later Acid Rocks, might be included here. Possibly in some or all of these we have remnants of the acidic earth-shell the formation of which marked the beginning of geological time.

At Leonora occurs a finely foliated much granulated quartz andalusite schist of sedimentary origin (Maitland, 1909, Clarke, X1), and in other places in the Leonora-Duketon district metamorphic rocks of clastic origin, including a black carbonaceous chiastolite slate, have been found (Clark X1).

At Quinn's (Feldtmann, 1921*b*) is a series of quartz-andalusite and quartz-chlorite gneisses and chlorite-talc schists with probable andalusite, which resemble lithologically the rocks just described. Feldtmann, however, regards the Quinn's rocks as representatives of the Mosquito Creek Series, whereas the other occurrences described in this section are thought to form the basal members of the Pre-Cambrian Group.

In the West Province several isolated occurrences of exceedingly metamorphosed sediments, apparently the bottom series of the Pre-Cambrians, are recorded:—

In the Phillips River District (Woodward, 1909) at least three occurrences of andalusite schist have been noted, and it seems likely that the acid schists, classed by Maclaren (Montgomery & Maclaren, 1914) as the oldest rocks of the district are also part of this series. Near Kendenup and along the Kalgan River also the country is composed of highly metamorphosed and sheared ancient sediments tilted at a high angle (Woodward & Blatchford, 1917).

Regarding the western part of this Province the late Mr. H. P. Woodward was of opinion (letter to myself) that the "Darling Range granites" are mainly metamorphosed sediments. Mr. Woodward was approaching the completion of an extended report on the South-West Division when he died, and not the least of the misfortunes accruing to geological science from that untimely event is that we have not the benefit of his matured opinion on the geology of this area. Apart, however, from the general question of the true nature of the main mass of the Darling Range granites, further information on which will be found in the section on Later Acid Rocks, the following occurrences of probable metamorphosed sediments in the Western Province may be noted:

At Northampton (Maitland, 1903) is a strong development of gneiss, mica-schist and quartz schist, in places garnetiferous, which may be of sedimentary origin. Near Moora (Blatchford, 1912) occur quartzites cut by greenstones which also cut the granite. Woodward (1912*c*) and Montgomery (1909) indeed, respectively regarded them as Mesozoic and late Palæozoic, but, judging from their relation to the greenstones, they would certainly seem to be Pre-Cambrian. Near Mogumber, where a staurolite schist occurs (Simpson, 1921), and again at Mooliabeenee, Mr. G. S. Compton and myself have noted gneissic and schistose rocks, the field-characters of which indicate a sedimentary origin.

Possibly here should be placed a series of highly metamorphosed sediments reported to occur south of Toodyay, and also the schists north of Toodyay (Maitland, 1899) and at Wongan Hills (Maitland, 1899).

Along the front of the Darling Range at Armadale, Cardup and other places (Honman, 1912) is a narrow band of quartzite and phyllite bordered on both sides, and possibly invaded, by epidiorite. Saint Smith (1912) considers it to be a part of the Donnybrook-Collie Permo-Carboniferous rocks, nipped-in in the parallel system of faults which constitutes the "Darling Fault." Contact-metamorphic effects are, however, reported to occur in these shales and quartzites and this, if confirmed, shows that they must be older than the epidiorites. On the other hand there is some evidence in support of the view that the phyllites are merely excessively sheared zones in epidiorite dykes and that the "quartzites" are really great quartz reefs. The true nature of the Armadale belt of rocks, close to Perth, is a problem awaiting solution.

In parts of the North-West Province occurs a series, called the Warrawoona Beds, consisting essentially of greenstone schists of various types, both basic and ultra basic, originally (Maitland, 1908) regarded as being not only the oldest rocks in the areas in which they outcrop but also as being metamorphosed sediments.

One would therefore be inclined to regard the Warrawoona Beds as contemporaries of the Yilgarn Series of the country farther south. However, Professor Sir Edgeworth David and Dr. E. S. Simpson have lately examined typical exposures of the Warrawoona Series, and Dr. Simpson informs me that they both agree that the Warrawoona Series is identical lithologically with the sheared greenstones (styled the Kalgoorlie Series in this address) of the Central Province.

It seems more likely that certain other rocks in the North-West Province are metamorphosed sediments and are to be included in the Yilgarn Series: such are the rocks between the Wooramel and Arthur rivers and at Bangemall and Station Peak (Maitland, 1909, Woodward, 1911) which are said to be sediments metamorphosed to quartz and mica schists, marble, etc., and cut by both granite and greenstone—the latter at Bangemall being identical petrologically with the gold-bearing greenstones of the Central Province.

In the East Province, near Mt. Aloysius, there is apparently (Talbot and Clarke, 1917) a considerable development of highly metamorphosed sillimanite schists, quartzites, etc. The relation between these rocks and the regional gneisses of the area has not been determined, so that their position in the Pre-Cambrian sequence is quite unknown, but, from their lithological resemblance to rocks of the Yilgarn Series in other parts of the State, they may tentatively be placed here in the sequence.

B.—Kalgoorlie Series.

This term, used by Honman (1916), is convenient in that the series is typically developed at Kalgoorlie and, at nearly every gold-mining centre, is the "country" of the gold-bearing lodes which the word "Kalgoorlie" naturally suggests. It is indeed applied by Maitland (1919) only to the sedimentary facies of the series, but, despite the danger of confusion arising from the use of the term with two significations, I have not been able to think of any other nearly as apt.

The series consists of a metamorphosed set of more or less contemporaneous basic, intermediate and acid lavas, dyke rocks and pyroclastics. The basic facies consists mainly of metamorphosed dolerites, basalts and gabbros with local ultrabasic developments. These rocks are frequently termed diorites in the older geological reports, and the name has survived in everyday language, but the only recorded occurrence of true diorite is at Tampa (Farquharson in Jutson, 1917, p. 39). The basic facies is widely distributed throughout the State (as already remarked in the section on the relation between granite and greenstone), and is very important economically; it has therefore been more studied and consequently more subdivided than other portions of the series.

At Kalgoorlie, Feldtmann (1916) found that the oldest rocks of the series are the "older greenstones"—which are probably metamorphosed lavas. He found no evidence of the existence of pyroclastics which are strongly developed in other parts of the State. Probably a little later than these are the rocks of White Cliff quarry, which he considers to be sheared porphyrites. We may note here that at Gibraltar a porphyrite occupies the same relative position in the sequence (Blatchford, 1913). Apparently cutting these ancient lavas is a somewhat later series of metamorphosed basic rocks—the younger greenstones—which were probably injected as one great dyke in which differentiation went on after intrusion. The extreme of this differentiation is found in the peridotites and their derivatives. Feldtmann states, however, that the evidence favouring the distinction between newer and older greenstones is scanty. Metamorphosed sediments, to which little attention has been given, occur, apparently near the top of the series, but Feldtmann disagrees with Honman's (1916) diagnosis of the graphitic schists of Kalgoorlie as metamorphosed sediments. Detail regarding the succession at Kalgoorlie is readily obtained from the valuable bulletin (Feldtmann, 1916) already quoted. In this bulletin will also be found references to important papers, some of which, such as Larcombe's * and Thomson's, † are not listed in Section VIII.

A very similar sequence has been found in the country south of Kalgoorlie where there is, however (Honman, 1916), a large development of sediments, and of an acid facies of igneous rock.

Again in the Norseman district Campbell (1906) found that the oldest rocks are amphibolites interbedded with sandstones and conglomerates, which, being earlier than the quartz veins, are probably comparable with the sediments of the Kalgoorlie series at Kalgoorlie, despite their comparatively unaltered character.

The same general features in the Kalgoorlie Series have also been recognised in the Monger-St. Ives district (Clarke, X3) although no clear evidence of the existence of two sub-series of greenstones was obtained. Both here and at Bulong (Feldtmann, 1919) there is a much greater development of the porphyrite member of the series than at Kalgoorlie.

In the Southern Cross greenstone belt there is apparently no representative of the porphyrites and sediments of the Kalgoorlie series (the important metamorphic sediments of this area have been placed in the older Yilgarn Series) except indeed that Honman believes that here, as in other regions studied by him (for example Yerilla—Honman, 1917), the jasper bars are bands of contempor-

* Larcombe, C. O. G.; The Geology of Kalgoorlie. Australasian Institute of Mining Engineers, Melbourne, 1913.

† Thomson, J. A.; The Petrology of the Kalgoorlie Goldfield. Quart. Journ. Geol. Soc., Vol. LXIX., 1913, p. 621.

aneous sediments (Blatchford & Honman, 1917, p. 158). Blatchford, however, considers the jasper bars studied by him to be crush zones in the foliated greenstones, and it may be noted further that, in the country immediately north of the Yerilla District and on jasper bars continuous with those mapped by Honman, the features stressed by him (1917, p. 23) as evidence of the sedimentary origin of the jasper bars could not be recognised with certainty (Clarke, X1).

Near Rothesay, in the Yalgoo Goldfield, the greenstones have an exceptionally basic aspect, and at Melville they exhibit many peculiarities owing apparently to refusion of the greenstone by the later granite (Clarke, X2).

In the northern part of the Central Province the Kalgoorlie Series is represented mainly by basic igneous rocks in which older and younger greenstones cannot be distinguished. Much attention, for example, was given both by Mr. Farquharson and myself to the various members of the Kalgoorlie Series at Meekatharra (Clarke, 1916) where, except for a small development of porphyrite, the basic igneous is the only facies represented, and we concluded that all the greenstones, which we subdivided rather elaborately according to the degree and character of their metamorphism, are derived from a common magma and that there is no evidence in the district of two ages of greenstone. The ultrabasic members of the group here, as in other parts of the State, are probably segregations from the doleritic magma and not separate intrusions.

In the north-eastern part of the Central Province there occurs a great belt of greenstones in which no subdivision on the score of age has been effected except in one or two remote and unimportant localities (Clarke, X1). The most marked characteristic of this region is the abundance of porphyrites, quartz porphyries, and rhyolites more or less contemporaneous with the ordinary greenstones. Thus, in the Leonora-Duketon District (Clarke, X1) is a development of rocks which were originally porphyrite and andesite flows and agglomerates, but which are now much altered in character. In one place the ordinary greenstones clearly cut the porphyrites. Somewhat similar rocks occur at Yilgangi (Honman, 1917) where, however, they are regarded as younger than the greenstones. Probably also the porphyritic greenstone of Mt. Ida and Sir Samuel (Gibson, 1907) is another development of the porphyrite facies. At Ora Banda (Jutson, 1914 *a*) porphyrite occupies the central part of the field, and is most likely derived from the same magma as the normal greenstones.

Again, a marked development of a still more acid phase of the Kalgoorlie Series is found between Duketon and Tampa. In Bulletin 84 (Clarke, X1) these rocks are described (see also Clarke, 1919) and some evidence is adduced for regarding them as con-

temporaneous with the greenstones and distinctly older than the intrusive granite. Mr. Farquharson suggests that they are the counterpart of the fuchsitic slaty porphyries of the "Golden Mile" and of a rock occurring as lenses in granite about seven miles east of Paddington (Feldtmann, 1915, p. 124). Similar rocks occur in widely scattered localities, for example: at Menzies (Woodward, 1906, and Clarke, 1919, p. 19), where is found a fuchsite andalusite schist; at Warrawoona (North-West Province), where occurs an andalusite rock which Simpson (Maitland, 1908, p. 156) regards as a metamorphosed felspar porphyry; at Goongarrie (foliated quartz porphyries, Jutson, 1921); at Payne's Find (Goodingnow) (Clarke, X2); at Kanowna, where some of the country originally described as sedimentary rocks more or less metamorphosed (Blatchford and Jutson, 1912) is stated in a later publication (Jutson, 1914 *d*) to be sheared quartz porphyry; at Gibraltar, the divergent views regarding which area have been noted under the Yilgarn Series; in the Norseman district, where Campbell (1906) notes the occurrence of quartz porphyries sheared to sericite schist (I have noted the same at Widgiemooltha and in the Monger-St. Ives district (Clarke, X3)). In the Norseman and Monger-St. Ives district the finer-grained acid and intermediate Pre-Cambrian rocks are divisible into older sheared, which may be classed with the Kalgoorlie Series, and younger unsheared. It may well be, however, that in many localities—for example, Kunanalling (Gibson, 1908), Cue (Woodward, 1914), Kurnalpi (Jutson, 1914)—this shear-structure is not necessarily an indication that the rocks affected are the older Pre-Cambrians, for it may have been produced in the later granitic rocks, during their intrusion which took place during a period of mountain building. The same explanation also may be advanced for Honman's gneissic granites (see further under Granite).

Metamorphosed rhyolites, no doubt the volcanic phase of the foliated quartz porhpyries just described, have been recognised in the Tampa area (Jutson, 1921) in the Yerilla District (Honman, 1917) and a little farther north near Melita (Clarke, X1).

In the Kalgoorlie Series we have the altered products of a long period of intense igneous activity which ensued when the first-formed acid shell cracked and to some extent foundered in the more basic substratum with consequent squeezing out of some of the basic magma. The basic was mixed with smaller quantities of more acid rock formed by the melting of portions of the acid shell. This period of igneous activity was a long one and obviously the lavas, tuffs, etc., of the earlier part of the period would be cut at different times by dykes originating from the same magma. During subsequent periods the whole series was metamorphosed into its present state. It seems, therefore, that the evidence obtained in different parts of the country regarding the occurrence of more than one age of greenstone must always be conflicting.

C.—Mosquito Creek Series.

In the North-West Province is found a large development of a series of sediments younger than the Kalgoorlie, but nevertheless somewhat metamorphosed, which are earlier than the granites and are gold-bearing. These are typically developed in Mosquito Creek, a tributary of the Nullagine River (Maitland, 1919, p. 17).

In dealing with the Yilgarn Series the possibility that some of the metamorphic sediments of this region are older than the Kalgoorlie Series and were laid down in Yilgarn times has been mentioned.

Regarding the Pre-Cambrian geology of the Kimberley Province we have as yet very little detailed information. It may be noted that Jack (1906) regards the granites seen by himself as the ultimate stage of metamorphism of the sedimentary "Silurian, Cambro-Silurian, or Cambrian" rocks, which being "metamorphic slaty schistose and gneissic rocks, carrying the auriferous bodies" of the area might belong either to the Kalgoorlie or to the Mosquito Creek Series. Dr. Simpson, however, informs me that all the rocks which he has seen from the gold-producing regions of the Kimberley are lithologically like the Mosquito Creek rocks and do not resemble the greenstones of the Kalgoorlie Series.

In the other provinces there are scattered occurrences of rocks best assigned to this place in the Pre-Cambrian sequence.

Woodward (1912) gave the rocks of this character occurring in the Peak Hill Goldfield the distinctive name of Gascoyne Series. Montgomery (1910, p. 61, and 1920) described them as metamorphosed sediments of later age than the Kalgoorlie Series and contemporaneous with the Mosquito Creek Series proper.

Talbot (1920) described rocks of similar character occurring in various places between longitudes 119° and 122° E. and latitudes 22° and 28° S. He nowhere, however, found the granite intrusive into these rocks. He classed the series as younger than the granite, thus assigning it to a horizon different from that given it elsewhere by other observers.

In the West Province also are several occurrences of metamorphosed rocks which, on available evidence and until more is known about the relative ages of the granites in different parts of the State, might almost equally well be classed with the Yilgarn or with the Mosquito Creek beds. Considering their generally advanced state of metamorphism they seem more appropriately placed in the older series, and a brief description of their distribution and content will be found under the Yilgarn Series. However, Woolnough (1920) concludes that the very striking exposure of quartzites, slates, quartz schists and mica schists in Stirling Range which are cut by granite and also by epidiorite may most reasonably be assigned to Mosquito Creek times.

In the Central Province, in the Warriedar district, metamorphosed sediments carrying auriferous and other ore-bodies at Yandhanoo Hill (Maitland, 1915, 1916, 1923, p. 36) and near Warriedar (Feldtman, 1921) appear to fall into this place in the sequence, though possibly they belong to the older Yilgarn Series. A band of metamorphosed conglomerate near Mt. Dennis (Talbot, 1920, p. 6) is also to be regarded as an outlier of the Mosquito Creek Series.

Honman's Kurrawang Series (1916 & 1914, p. 23), a set of somewhat metamorphosed sediments characterised mainly by strong development of conglomerates containing fragments of rocks of the Kalgoorlie Series, must also be grouped with the Mosquito Creek Series.

Scattered occurrences of somewhat metamorphosed coarse fragmental rocks in the East Province between the Warburton Range and the South Australian border (Talbot and Clarke, 1917, p. 94) may also belong to Mosquito Creek times.

D.—Later Acid Rocks.

A large part of the State is mapped as "Granite and Gneiss" (Maitland, 1919), also in nearly every mining centre are bars of acid rock intrusive into the Kalgoorlie or Mosquito Creek Series.

1. *Granite.*—The bulk of the "Granite and Gneiss" seems to come in this place in the Pre-Cambrian succession. No detailed systematic study of the Western Australian granites as a whole, or even of the granites of one area has yet been undertaken.

Many years ago Simpson (1909) defined at least three types of granite in the State; one barren of minerals of value, the second associated with ores of tin and tantalum, the third with ores of gold and copper. Dr. Simpson informs me that he still recognises these types and finds that the first is a microcline granite, the second a soda granite, the third a granodiorite. Mr. R. A. Farquharson, petrologist of the Geological Survey, has in conversation expressed the opinion that there are two main types of granite in the West and Central Provinces—a yellowish granite containing very little ferro-magnesian mineral (what there is being mainly biotite) and a greyish white biotite granite. Although one is struck by the number of recorded occurrences of hornblende granite, it may be that, as suggested by Woodward (1914) and Jutson (1921, *a* & *b*), the hornblende replaces the biotite by some endomorphic process near contact with the intruded rock, or as the result of slight dynamic metamorphism.

The main mass of the granite of the East, unlike that of the Central Province which is sheared mainly or solely along its margin, is, so far as known, a regional gneiss, consisting of large quartz and microcline crystals and a little hornblende. This rock neverthe-

less (Talbot & Clarke, 1917, pp. 90, 92) grades into great porphyry dykes which cut greenstones identical lithologically with those of the Kalgoorlie Series of the Central Province. The occurrence of charnockites (Farquharson—Talbot & Clarke, 1917, pp. 159-61) appears to be unique in this State. The abundance and size of the fresh gabbro and dolerite dykes which cut the granite of the East Province are noted in Section IV.

In the Central Province all observers agree that where the granite and the Kalgoorlie Series are in contact the granite is intrusive. It is only gneissic either along its contact with the older rocks or in restricted areas within the main body of the rock. The gneissic structure is thought to be due, partly to drag along contact with the intruded rock and partly to earth-movement during the mountain-building period which was responsible for the granite intrusion.

Probably the late Mr. H. P. Woodward devoted more attention than any other field-geologist to the characteristics of the Central Province granites. In the northern part of the Yilgarn Goldfield (1912) he distinguished hornblende-biotite granite, albite-muscovite granite, and orthoclase-biotite granite. The first and second he regarded as possibly metamorphosed sediments. In part of the Murchison Goldfield, centring round Cue, he (1914) found that a hard porphyritic muscovite granite intrudes the biotite granite which forms the bulk of the country and which cuts the greenstones of the Kalgoorlie Series. At Cue and Cuddingwarra he (1907) noted an exceptional granodioritic type which at Cue carries the chief auriferous bodies. Granodiorite is also known to occur at Kookynie, where Jutson (1921*a*, p. 38) regards it as a "magmatic variation of the granite."

At Meekatharra (Clarke, 1916) two varieties of the biotite-microcline granite have been recognised—the Southern Cross type, which has a prevalent yellow-brown colour, and carries pegmatites and some gold and copper deposits, and the Meekatharra type, which normally bears distinct signs of dynamic strain, and, though not itself ore-bearing, is probably the parent of the various porphyry dykes which in turn have a close connection with the chief gold-bearing bodies of the district.

The granite at Warriedar is unusually acid, being composed of quartz, oligoclase microcline and muscovite in varying proportions (Feldtmann, 1921).

Honman (Blatchford & Honman, 1917, p. 149, Honman, 1914, 1916, 1917) believes that in various parts of the Central Province the normal granite encloses patches of an older gneiss which is possibly a relic of the ancient basement on which the greenstones were deposited. However, in the country immediately north of the Yerilla district in which Honman found these older gneissic granites

and in several other parts of the Leonora-Duketon district (Clarke, X1) field and microscope evidence combine to show that the gneissic patches are merely local variations of the great granite batholith.

Gibson (1906) recognised two ages of granite near Burtville, but I have not been able to find any evidence in the field to support this view.

A problem awaiting final solution is that of the relationship of the hornblende-biotite gneiss, which so far has only been found at Westonia (Blatchford and Honman, 1917, p. 56) and at Payne's Find or Goodingnow (Clarke, 1920 & X2), that is at two mining centres near the western edge of the Central Province. At both places the hornblende-biotite gneiss carries auriferous bodies and is thought to owe its strongly gneissic character to lit-par-lit injection of quartz into a granodiorite. Field-work at Goodingnow led me to believe that the gneiss was formed by the injection of a belt of the epidiorite by a great number of pegmatite dykes, but this conclusion was not supported by detailed petrological work. Whether the original granodiorite was an acid segregation of, or an intrusion into the greenstone (in which latter case it would have an analogy in the granodiorites mentioned already) is not yet quite definitely settled, though Blatchford (1917, p. 56) holds strongly to the latter view.

It is very likely that, as detailed work is done on granite areas, patches of older rock will be discovered, just as rocks formerly mapped as granitic as Quinn's (Gibson, 1904) and Leonora (Jackson, 1904) have been shown afterwards (see section on Yilgarn Series) to be probably metamorphosed sediments.

In the West Province Aurousseau's work (1916) at Albany and at Roelands near Bunbury shows how much has yet to be done before we are in a position to generalise safely regarding the composition of the granite areas. At Albany the oldest rock is gneiss, in places garnetiferous, which is intruded by granodiorite. Later than both of these is microgranite. At Roelands, on the other hand, the gneiss has been produced from granodiorite very similar to the later rock at Albany.

The question of the possibly sedimentary origin of the West Province gneisses has already been raised in dealing with the Yilgarn Series. There seems to be general agreement that in the south-west part of the Province the gneiss has been formed by the shearing of an acid igneous rock which is, as already remarked, a granodiorite porphyry at Roelands. In this part the trend of the gneiss is apparently fairly regular (*e.g.*, Greenbushes—Feldtmann, 1914, p. 156, Bridgetown—Maitland, 1899, p. 23, Goomalling—Maitland, 1899).

In the Darling Range near Perth the acid rocks are in the main massive though in places (for example Darlington) the granite has been converted, along narrow zones, into quartz-sericite schist.

In the north part of the West Province (Campbell, 1910) east of the apparent continuation of the Darling Fault (Suess, 1906) are found granitic rocks of gneissic aspect. These gneissic rocks are well shown for example close to the fault-contact with Permo-Carboniferous rocks at Badgerer pool on the upper Irwin River.

A broken belt of gneiss lies west of the Darling Fault. In this belt the gneiss seems to be everywhere garnetiferous (between Capes Naturaliste and Leeuwin—Saint Smith, 1912, near Northampton—Feldtmann, 1920, p. 15, near Arrino and Mingenew—Campbell, 1910) and in the northern part carries lead and copper lodes. At Albany (which, however, lies too far east to be included in the belt just described) Aurousseau, as already noted, distinguishes an older gneiss which is intruded by granodiorite very like that of Roelands. Possibly the garnetiferous gneiss of the Leeuwin-Northampton belt is an older rock than the main body of granite, granodiorite and gneiss.

In the North-West Province granite is intrusive into the Mosquito Creeks beds and Maitland (1909) is inclined to distinguish two ages of granite near Roebourne. A granodioritic phase occurs at Mosquito Creek (Simpson, 1916, p. 20).

No detail regarding the Kimberley "granites" is available except Jack's opinion regarding their sedimentary origin which has been noted under the Mosquito Creek Series.

It is evident even from this imperfect summary that there are many unsolved problems regarding the Western Australian granites, but it may be suggested that the "granite and gneiss" of the most recent geological map of the State, include rocks of at least two very different ages. In the East and West Provinces some of the gneisses may be highly metamorphosed sediments, inextricably mixed with remnants of the first earth-shell of acid composition. In the Central Province the granite is in the main rejuvenated earth-shell, fused by deep burial and folding and thrust up, as great batholiths among the Yilgarn, Kalgoorlie, and Mosquito Creek rocks.

2. *Acid Dykes—apophyses of the granite.*—In almost every mining centre of the Western Australian Goldfields occur acid dyke rocks intrusive into the gold-bearing (Kalgoorlie or Mosquito Creek) series. The opinion has been expressed by many observers that these dykes, though few are themselves auriferous, have a close connection with the origin of the lodes or veins, and that, though comparatively few can be traced into the granite, they are really offshoots from that rock. The acid dykes vary in coarseness of grain and somewhat in mineral composition, but it seems, judging from the more exact petrological determinations made of late years, particularly by Dr. J. A. Thomson and Mr. R. A. Farquarson, that the dykes most commonly associated with auriferous

bodies are albite porphyry and albite granite. There is some conflict between this statement and Dr. Simpson's opinion quoted previously that soda granites are associated rather with ores of tin and tantalum, granodiorite being the companion of gold deposits.

3. *Porphyrite Dykes.*—These are apparently a series distinctly younger than the porphyrites which form part of the Kalgoorlie series. So far they have been noted almost solely in the country at Kalgoorlie and, farther south, at Bulong where Feldtmann (1919) distinguishes a series of porphyrite and porphyry dykes younger than his series of porphyrites and porphyrite breccias, and in the Monger-St. Ives district where a similar sub-division of the porphyrite rocks was made independently (Clarke X3).

4. *Latest Acid Intrusions.*—In nearly all the granite areas of the State occur pegmatite veins cutting the granite and all earlier rocks. Probably, however, these pegmatites are not much younger than the granite which they intrude, being merely the ultra-acid residual matter of the granite magma which was forced into the cracks formed in the cooling mass of granite.

However, it appears that, at least in the Western Province, pegmatites of two ages occur. In the majority of places, *e.g.*, Greenbushes (Feldtmann, 1914) near Goomalling (Jutson, 1912), between Capes Naturaliste and Leeuwin (Saint Smith, 1912) the pegmatite dykes are intrusive into the epidiorite dykes which in turn are intrusive into the granite, whereas at Boya, near Perth, small epidiorite dykes cut the pegmatites, and at Albany, Aurousseau (1916) distinguishes an earlier epidote-biotite pegmatite from a later series of pegmatites.

E.—Nullagine Series.

The "Nullagines" are basic igneous flows and pyroclastics with conglomerates, quartzites, sandstones, grits, shales, limestones and dolerites. The distribution and character of the main areas of this series, which are found in the Kimberley and North-West Provinces, are described by Maitland (1919) and Simpson (1923). In the Central and West Provinces, in addition to the outliers of the series mentioned by Maitland (1919) several other occurrences of unmetamorphosed rocks, uncomformably overlying all the series described above, may, lacking more definite evidence, be classed as Nullagine. Thus, as well as the "ancient sediments and associated igneous rocks" of Mt. Singleton and the horizontally bedded rocks of Mt. Yagahong (Clarke, 1916, p. 72) and other places assigned by Maitland (1919) to this series, we might include in it the gently inclined beds of lava,* pyroclastics and sediments of Billeranga Hills; the exactly similar quartzoze conglomerates underlain by basic volcanics which form a

* One of which, Dr. Simpson informs me, is a much weathered orthoclase dolerite.

prominent escarpement at "Granite Hill," near Yandanooka; the tuffs, sandstones and conglomerates of Three Springs (Feldtmann, 1919); and the uncrushed quartzites and conglomerates of Mt. Jackson Range (Blatchford and Honman, 1917, p. 161).

The scattered areas of metamorphosed sediments found in the Central and West Provinces are placed, according to the intensity of their metamorphism, either with the Yilgarn or with the Mosquito Creek Series.

The suggestion is made by Talbot (1920) that certain fine-grained amphibolised and zoisitized dolerites which probably cut the Kalgoorlie Series in the North-West Province are of the same age as the lavas forming part of the Nullagine Series. One would be tempted therefore to correlate with these the epidiorite dykes cutting the granites, etc., of the West Province, but, since the epidiorites have suffered considerable dynamic metamorphism, while the supposed Nullagine amphibolised and zoisitised dolerites of the West Province are not metamorphosed, this is hardly possible. Nevertheless, it would be well worth while to determine definitely the relationship of epidiorites and "Nullagines" in the West Province, and, for such an investigation the neighbourhood and Billeranga Hills appears well suited.

Attention may be drawn to the fact that while Talbot (1920) considers the Carawine limestones to be Post-Carboniferous, Maitland (1919, p. 28) places them in the Nullagines.

Finally, it may be said with regard to the Nullagine Series that the question of its inclusion in the Pre-Cambrian Group is in doubt. As the result of work in the East Province, Mr. Talbot and myself were led (1917, more detail in 1918, see also Maitland, 1919, p. 27) to suggest that the series is of Ordovician age. Although the evidence is not very strong, it is at present a little more convincing than that on which a Pre-Cambrian age is assigned to the series.

VI. Unmetamorphosed Basic Dykes.

Reference must be made to the ubiquitous series of later unmetamorphosed basaltic dolerite dykes and larger masses of gabbro and norite. These rocks form prominent surface features in the East Province (Talbot and Clarke, 1917), in the North-West Province (Talbot, 1920), and in the Central Province (Norseman District, Campbell, 1906, and Clarke, X3; Barloweerie Peaks, Clarke, 1916). In the Central Province they are also found in mine-workings in many places where no sign of their presence can be detected at the surface (Talbot and Clarke, 1917, footnotes, p. 99). An unusual type from Kalgoorlie and St. Ives has recently been described by Farquharson (1923). In age these rocks are probably Mesozoic or Tertiary (Clarke, 1916, p. 64, and Talbot, 1920), but they are so

commonly found intrusive into the Pre-Cambrians that no description of the group, however brief, would be complete without mentioning them.

VII. Summary.

It is quite unnecessary after what has been said in the preceding part of this paper to stress the fact that the classification suggested makes no pretence at finality. The paper will, however, be of use if it directs the attention of our geologists to some unsolved problems of importance in the ancient rocks of our State.

I suggest then that our "Pre-Cambrian" rocks comprise the following series, beginning with the oldest:—

A. *Yilgarn Series.*—Occurring in comparatively small patches amongst younger Pre-Cambrian rocks. Chiastolite, andalusite, mica and other schists—largely of sedimentary origin, also gneisses, some of sedimentary, some of igneous origin, probably remnants of first (acid) earth-shell.

B. *Kalgoorlie Series.*—Occurring in the Central, North-West and East Provinces in numerous island-like patches in the much larger area of granite. Predominantly basic igneous rocks metamorphosed to epidiorites, etc. Minor developments of ultra-basic and acid igneous and of sediments. Probably intrusive into Yilgarn Series.

C. *Mosquito Creek Series.*—Main development in North-West Province. Sediments, metamorphosed, but not so strongly as those of the rocks of the older series. Clearly younger than Yilgarn and Kalgoorlie Series.

D. *Later Acid Rocks.*—Most extensively developed portion of the whole Group. Predominantly granite—in some places gneissic. Younger than any of preceding series as judged by character of its contact with them, yet probably includes patches of much greater age.

E. *Nullagine Series*—but possibly Ordovician—sediments and basic igneous flows and dykes not affected by regional metamorphism. Youngest series of epidiorite dykes—which has greatest development in West Province—can only be a little older than the Nullagines.

I suggest also that the "Pre-Cambrian" areas of the State may be divided into the following "Provinces"—four of which are known to have distinctive characteristics:—

East Province.—Regional Gneisses. Charnockites. Great dykes of unaltered basic rocks, which are younger than any of the epidiorites. East and West trend of greenstones belts.

Central Province.—Maximum development of Kalgoorlie Series with general N.N.W. trend. Almost entire absence of youngest series of epidiorite dykes.

West Province.—Maximum development of youngest epidiorite dykes. Strong development of massive and gneissic granite.

North-West Province.—Maximum development of Mosquito Creek and Nullagine Series, East and West trend-lines marked, N.N.W. trend-lines also represented.

Kimberley Province.—Characteristics unknown.

I have purposely avoided all attempt at correlation with other Pre-Cambrian regions.

VIII.—Bibliography.

The following list of papers quoted in this contribution is not a complete bibliography of the Pre-Cambrian geology of Western Australia. Some papers which marked most important advances in the knowledge of the subject, such as Simpson's* and Thomson's,† will not be found here, because the conclusions stated therein have been generally accepted and are now common knowledge. I have included in the list three reports by myself, which, like several other bulletins, have been awaiting publication for two years and more. I have done this, because I believe the areas described in those reports display the true character of the older part of the group and because it was field work in them which enabled me to form some opinion regarding the order of succession in the Pre-Cambrian rocks.

Titles of papers are much shortened, and, besides ordinary contractions, the following abbreviations are used:—

A. Annual Progress Report of the Geological Survey of Western Australia for the year.....

B. Geological Survey of Western Australia, Bulletin No.....

Aurousseau, M.	**1916**	Western Australian gneissic and granitic rocks. Proc. Linn. Soc. N.S.W., Vol. XLI., Part 2, p. 261.
Blatchford, T.	**1912**	Possibilities of artesian water near Moora. B. 48, p. 56.
	1913	Burbanks and Londonderry. B. 53.
	1917	Graphite at Munglinup. B. 76.
	1919	Asbestos East of Moora. A. 1918.
Blatchford, T., and Jutson, J. T.	**1912**	Kanowna. B. 47.
Blatchford, T., and Honman, C. S.	**1917**	Yilgarn Goldfield, Part III. B. 71.
Campbell, W. D.	**1906**	Norseman. B. 21.
	1910	Arrino-Northampton. B. 38.

* Simpson, E. S.; "Notes from the Departmental Laboratory," p. 62; "Rocks of Kalgoorlie," Western Australia. Geol. Survey. Bulletin No. 6.

† Op. cit.

Clarke, E. deC. ...	... 1916	Meekatharra. B. 68.
	1919	Leonora-Duketon and Menzies. A. 1918.
	1920	Goodingnow, Rothesay, and Noongal. A. 1919.
	1921	Monger-St. Ives. A. 1920.
	x1	Leonora-Duketon. B. 84 (not yet published.)
	x2	Goodingnow, Rothesay, and Noongal. B. 86. (Not yet published.)
	x3	Monger-St. Ives. B. 90. (Not yet published.)
Farquharson, R. A.	... 1923	Olivine Picrite at Kalgoorlie. Journ. and Proc. Roy. Soc. of W.A., Vol. IX. Part 1., p. 23.
Feldtmann, F. R.	... 1914	Kapanga Mine, Greenbushes. B. 59, p 56.
	1915	Mulline, etc. B. 64, p. 133.
	1916	Kalgoorlie. Part III. B. 69.
	1919	(*a*) Bulong. B. 82.
		(*b*) Clay at Three Springs. A. 1918.
	1920	Clay at Bolgart. A. 1919.
	1921	(*a*) Northampton. A. 1920.
		(*b*) Quinn's and Jasper Hill. B. 80.
		(*c*) Warriedar. B. 81.
	1922	Gibraltar. A. 1921.
	1923	Youanmi. A. 1922.
Gibson, C. G. ...	... 1904	Part of Murchison Goldfield. B. 14.
	1906	Laverton, Burtville and Erlistoun. B. 24.
	1907	Lawlers, Sir Samuel, Darlot, Mt. Ida. B. 28.
	1908	Bonnievale, Kunanalling, and Black Range. B. 31.
	1909	Transcontinental Railway route. B. 37.
Honman, C. S. ...	... 1912	Kelmscott Clay. B. 48, p. 63.
	1914	(*a*) Bremer Range. B. 59, p. 190.
		(*b*) Kalgoorlie-Coolgardie. B. 56.
	1915	Mt. Jackson-Koolyanobbing. A. 1914.
	1916	Country South of Kalgoorlie. B. 66.
	1917	Yerilla, B. 73.
Jack, R. Logan ...	... 1906	Artesian Water in Kimberley. B. 35.
Jackson, C. F. V.	... 1904	Leonora. B. 13.
Jutson, J. T. ...	... 1912	Darling Plateau. B. 48, p. 138.
	1914	(*a*) Ora Banda. B. 54.
		(*b*) Kurnalpi, B. 59, p. 13.
		(*c*) Yuin. B. 59, p. 140.
		(*d*) Further Notes on Kanowna. B. 59. p. 215.
	1917	Golden Butterfly Mine. B. 74.
	1921	(*a*) Kookynie, Niagara, and Tampa. B. 78.
		(*b*) Comet Vale and Goongarrie. B. 79.
Maitland, A. G. ...	... 1899	Wongan Hills, Blackboy Hill, Bridgetown, etc. A. 1898.
	1903	Northampton. B. 9.
	1908	Pilbara Goldfield. B. 40.
	1909	Parts of Peak Hill, Gascoyne, and Ashburton Goldfields. B. 33.
	1910	Leonora. A. 1909, p. 14.
	1916	Mt. Singleton and neighbourhood. A. 1915, p. 6.
	1917	Mt. Singleton and neighbourhood. A 1906, p. 9.

Maitland, A. G.	1919	Summary of Geology of Western Australia. Geol. Surv. of W.A., Memoir No. 1, Chapter I.
	1919	Gold Deposits of Western Australia. Geol. Surv. of W.A. Memoir No. 1, Chapter II., Part III. Section I.
Montgomery, A.	1908	Quartz Reefs at Wagin. Report of Department of Mines, of W.A. for 1907, p. 91.
	1909	Guano near Watheroo. Report of Department of Mines of W.A. for 1908, p. 66.
	1910	State of Mining in certain centres in Murchison and Peak Hill Goldfields. Department of Mines of W.A.
	1902	Manganese at Horseshoe. Government Printer, W.A.
Montgomery, A. and Maclaren, M.	1914	Phillips River Mines. Department of Mines of W.A.
Saint-Smith, E. C. ...	1912	South-West Division. B. 44.
Simpson, E. S.	1909	Types of W.A. Granite. A. p. 7.
	1916	Analyses of W.A. Rocks, etc. B. 67.
	1921	Staurolite from Mogumber. Journ. and Proc. Roy. Soc. of W.A., Vol. VII., p. 71.
	1923	Sulphates and Chert in Nullagine series. Journ. and Proc. Roy. Soc. of W.A., Vol. IX., Part 2.
Suess, E.	1906	The Face of the Earth. English translation. Vol. II.
Talbot, H. W. B. ...	1920	(*a*) Zanthus to Laverton. A. 1919. (*b*) South part of Yalgoo Goldfield. A.1919. (*c*) Parts of North-West, Central and Eastern Divisions. B. 83.
Talbot, H. W. B., and Clarke, E. deC.	1917	Laverton to South Australian Border. B. 75.
	1918	Expedition to South Australian Border. Jour. and Proc. Roy. Soc. of W.A., Vol. III., p. 70.
Woodward, H. P. ...	1895	Mining Handbook of W.A. Second Edition, Perth, Government Printer.
	1906	Menzies. B. 22.
	1907	Cue and Day Dawn. B. 29.
	1908	Greenbushes, etc. B. 32.
	1909	Phillips River Goldfield. B. 35.
	1911	West Pilbara Goldfield. B. 41.
	1912	(*a*) North part of Yilgarn and South part of North Coolgardie Goldfields. B. 46. (*b*) Country at heads of Gascoyne and Ashburton Rivers. B. 48. (*c*) Watheroo. B. 48, p. 22.
	1914	Part of Murchison Goldfield. B. 57.
Woodward, H. P., and Blatchford, T.	1917	Kendenup Graphite. B. 74, p. 95.
Woolnough, W. G. ...	1920	Stirling Ranges. Journ. and Proc., Roy. Soc., N.S.W., Vol. LIV., p. 79.

IX.—Location of Places mentioned in Text.

After each locality is put, first its approximate south latitude, second its approximate east longitude. Location of a goldfield is to about its middle, of a river to its mouth.

I am greatly indebted to Mr. A. Gibb Maitland, Government Geologist, for permission to attach uncoloured prints of the Geological Map of Western Australia.

Albany 35°, 117° 50.
Armadale 32° 10, 116°.
Arrino 29° 30, 115° 40.
Arthur River 25°, 115° 25.
Ashburton Goldfield 22° 50, 115° 30.
Badgerer Pool 28° 50, 115° 40.
Bangemall 24°10, 116° 50.
Barloweerie Peaks 26° 45, 118°.
Billeranga Hills 29° 20, 115° 50.
Bolgart 31° 20, 116° 30.
Boya 31° 50, 116° 10.
Bridgetown 34°, 116° 10.
Bullfinch 31°, 119° 10.
Bulong 30° 40, 121° 40.
Bunbury 33° 20, 115° 40.
Burtville 28° 45, 122° 40.
Canning River 32°, 115° 40.
Cape Leeuwin 34° 20, 115° 10.
Cape Naturaliste 33° 30, 115°.
Cardup 32° 15, 116°.
Collie 33° 20, 116° 10.
Comet Vale 29° 55, 121° 10.
Condon 20°, 119° 30.
Coolgardie 30° 55, 121° 10.
Corunna Downs 21° 30, 119° 50.
Cuddingwarra 27° 20, 117° 50.
Cue 27° 25, 118°.
Darling Range 31° 30, 116° 10.
Darlington cp. Boya.
Derby 17° 20, 123° 50.
Donnybrook 33° 30, 115° 50.
Duketon 27° 40, 122° 10.
Eenuin 30° 45, 119.
Eramurra Creek 21°, 116° 15.
Forrestania 32° 30, 119° 50.
Gascoyne Goldfield 24° 20, 116° 20.
Gibraltar 31°, 121°.
Goodingnow 29° 15, 117° 40.
Goomalling 31° 20, 116° 50.

Goongarrie 30° 05, 121° 10.
Greenbushes 34°, 116°.
Irwin River 29° 15, 114° 50.
Kalgan River cp. Albany.
Kalgoorlie, 30° 45, 121° 30.
Kanowna 30° 35, 121° 30.
Kendenup 34° 30, 117° 40.
Kookynie 29° 20, 121° 30.
Kunanalling 30° 40, 121° 05.
Kurnalpi 30° 30, 122° 10.
Leonora 28° 50, 121° 20.
Marvel Loch 31° 30, 119° 40.
Meekatharra 26° 35, 118° 25.
Melville, *see* Noongal.
Menzies 29° 40, 121°.
Mingenew 29° 10, 115° 25.
Mogumber 31°, 116° 05.
Monger 31°, 121° 50.
Mooliabeenee 31° 20, 116° 10.
Moora 30° 40, 116°.
Mosquito Creek 21° 50, 120° 30.
Mount Aloysius 26°, 128° 30.
Mount Dennis 29°, 122° 50.
Mount Ida 29° 15, 120° 25.
Mount Jackson 30° 15, 119° 20.
Mount Kenneth 29°, 118° 10.
Mount Samuel 24° 20, 116° 30.
Mount Singleton 29° 30, 117° 20.
Mount Yagahong 26° 50, 118° 35.
Murchison Goldfield 26° 50, 117° 30.
Noongal 28° 10, 116° 45.
Norseman 32° 10, 121° 50.
Northampton 28° 20, 114° 40.
Nullagine 21° 50, 120° 15.
Ora Banda 30° 20, 121°.
Paddington 30° 30, 121° 20.
Parker Range 31° 40, 119° 20.
Payne's Find, *see* Goodingnow.
Peak Hill Goldfield 24° 55, 117° 40.
Perth 32°, 115° 50.
Phillips River Goldfield 33° 10, 120°.
Pilbara Goldfield 21°, 119° 30.
Quinn's 27°, 118° 35.
Ravensthorpe 33° 30, 120° 10.
Roebourne 20° 40, 117° 10.
Roelands 33° 15, 115° 45.
Rothesay 29° 15, 116° 50.
Sandstone 28°, 119° 20.

The Hon. J. Scaddan M.L.A.
Minister for Mines

GEOLOGICAL SKETCH MAP OF WESTERN AUSTRALIA.

BASED ON THE WORK OF THE GEOLOGICAL SURVEY.

A. GIBB MAITLAND
GOVERNMENT GEOLOGIST.

1920

Scale of English statute miles
50 40 30 20 10 0 50 100 150 200

REFERENCE

Towns	shown thus ⊙ EUCLA
Railways	
Land District Boundaries	
Land Division	
Goldfields	
Telegraph Lines & Stations	
Lighthouses	
Stock Routes	
Heights in feet	(3600)
Steamer Routes	

Geology compiled by F. R. Feldtmann

LEGEND.

CAINOZOIC — κ — Tertiary and Post-Tertiary. Coastal limestones. Pinnacle Rock Beds, alluvium, etc.

MESOZOIC — cr — Cretaceous; J — Jurassic and undifferentiated Cretaceous

PALÆOZOIC — c — Permo-Carboniferous and Carboniferous; d — Devonian; Or — Ordovician; Cm — Cambrian

(Post and Upper Proterozoic) — n — Nullagine (Algonkian conglomerates in places)

PROTEROZOIC — m — Mosquito Creek and Stirling Range Beds (Auriferous reefs in places)

ARCHÆOZOIC — a — Undifferentiated metamorphic rocks (Auriferous reefs in places)

IGNEOUS — G — Granite and gneiss; P — Porphyries and porphyrites; B — Basalt; D1 — Dolerite dykes and sills (Post gold "greenstones"); D — Gabbro dolerite, epidiorite, serpentine, etc (Pre-gold "greenstones")

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